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Remarkable events in the knee region and abnormal behaviour in EAS data

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Abstract

We investigate the consequences of the diquark breaking mechanism near the Knee region on remarkable events coplanar emission, different conversion of visible energy to primary energy, multicluster production.

The general threshold of 8 PeV for coplanar emission (estimated from classical multiproduction) could be reduced to 3-4 PeV in coincidence with the Knee. At higher energy, the complete suppression of the leading particle effect could explain the disappearance of fragmentation region of very high energy γ's in EAS at mountain altitude. It could also explain why T_{max} levels off between 3 PeV and 100 PeV.

1. The diquark breaking mechanism

One on the basic features of ultra high energy interactions is the separation of one valence quark slowed down during the collision from a fast diquark, which is recombined after the interaction with one quark from the sea. This recombination gives usually directly a new proton leader, or indirectly, after formation of an excited leading cluster, for instance through a Δ resonance, a new proton leader. In all cases this proton leader can carry out a large part of the primary energy (30 to 60 %) and survives to several collisions, providing energy to the shower development in the atmosphere.

Some diquark breaking diagrams [3] are plotted on fig.1. Taking into account the quark content and the quark additive model, we observe that the 3 valence quarks can be recombined respectively with antiquarks of the sea, giving mesons from simple pairs, such as $|u\bar{d}> (\pi^+)$, $|\bar{u}d> (\pi^-)$ or more complex combination such as $\frac{1}{\sqrt{(2)}}|d\bar{d} - u\bar{u}> (\pi^o)$ or $\frac{1}{\sqrt{(2)}}|d\bar{d} + u\bar{u}> (\eta)$.

Among the different outputs of the quark flow diagram resulting from the diquark breaking mechanism, one configuration with 3 π^o's can emerge with a probability 1/27.

Such circumstance (with intermediaire output states of the higher probability containing one pair of charged pions, accompanied by one π^o, 2 π^o's accom-

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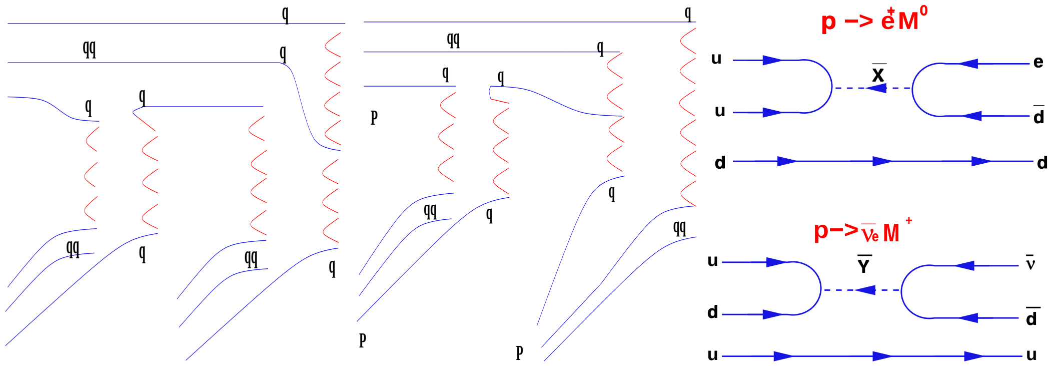


Fig. 1. a and **b** feynmann diagrams of diquark breaking. **c**: An example of leptoquarks (diquark bosons) for diagram in leading cluster.

panied by one charged pion or 3 charged pions) will transfer a large part of the primary energy to the electromagnetic component, missing for the hadronic and the penetrating components.

At the energy of the Knee (3-4 PeV), the energy in the center of mass of a valence quark and one quark of the target is sufficient to generate particles of 300-400 GeV. This corresponds for instance to the hypothesis of White [4] introducing a sextet quarks and new baryons of masses near 400 GeV: the theory contains also colour octet quarks q_8 which could be leptoquark. The baryons generated in the diffractive collisions are semi-stable with decay modes including multiproduction of W's and Z's.

Another mechanism concerning the diquark fragmentation could be found in SU(5) with the diquark bosons or leptoquarks (fig.1.). Those diagrams originally used for the proton decay could be used if the $\bar{X}$ and $\bar{Y}$ leptoquark have masses near 400 GeV, to give leading clusters such as $\bar{\nu_e}$+π^+ or e^+ + π^o.

2. The coplanar emission

The energy threshold of registration of coplanar emission is about 8 PeV [1]. In principle, the event (JFaf2) observed in the Concorde (fig.1.b) with a visible energy of 1600 TeV enters in the same energy that the events registrated in the Pamir experiment. By simulations with CORSIKA, we have demonstrated (fig.2.a), that normal fluctuations could produce such alignements of γ's. However, such fluctuations results from events produced about 10 km above the chamber in the statosphere. This doesn't agree with our previous estimation of the altitude of the collision of 60-100 m above the chamber: this estimation [2] was done by the method of the invariant mass on the γ's of the different clusters of JF2af2 coupling in π^o's. It remains also difficult to explain why one third of the visible energy is concentrated on the 3 most energetic γ's. The observation of a primary particle of about 10 PeV during the exposure at 100 g.cm^{-2} of 3 emulsion chambers of 40×50 cm area during 200 hours or 400 hours is extremely improbable, in regard of the primary spectrum intensity estimated from EAS. This emphaszes the interest of the electromagnetic outputs of the diquark breaking mechanism (3 π^o, $\pi^o + \bar{\nu}_e$ for the leading cluster) reducing by a factor 2 the conversion to the primary energy. In those cases, the energy threshold for coplanar emission would correspond approximately to the energy of the Knee. The mechanism advanced by White for the alignement deals with the center of mass of the scattered valence quark and the diquark system, the q$\bar{\text{q}}$ pairs being produced at rest: the full diffractively produced state is approximately coplanar, lying the plane formed by the moment of the fast going forward baryon and the anti-baryon of the smallest forward momentum. We propose a different synopsis to explain the alignement by diquark breaking. The diquark is uu (with probability 1/3) and ud (with probability 2/3). In this last case, we can consider the center of mass of the system du-u. The u quark is scattered first and the diquark breaking of the system du goes like a fission, with an ellipsoid deformation. The d quark is scattered in the direction of the u scattered quark, and the major axis of the ellispoid contains the 3 valence quarks.

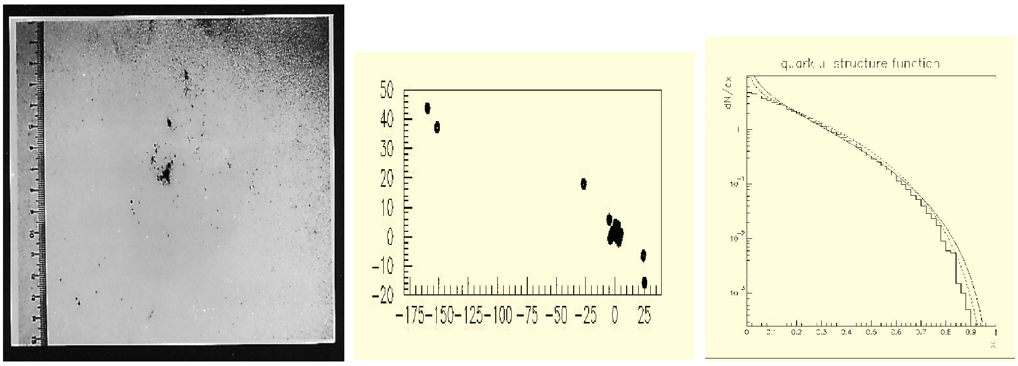
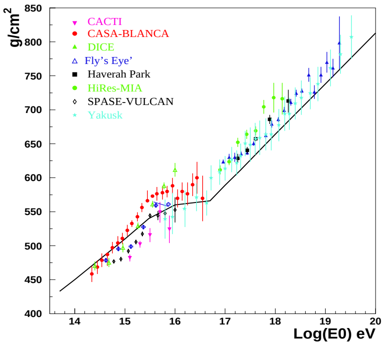


Fig. 2. a Event JFaf2 observed at the Concorde. **b** Simulation with CORSIKA. **c** the structure functions of the 3 valence quarks

3. Diquark breaking and extensive air showers

The suppression of the leader outgoing proton indicates that the energy carried by the 3 valence quarks determined from the structure functions reproduced on fig.3.a are transmitted to the secondaries at the first collision.

The depth of the maximum obtained assuming that the diquark breaking occurs at 2.5 PeV for protons (10 PeV for α's, 40 PeV for LH's, 100 PeV for VH's) has been calculated for a mixed component (40 % p, 30 % α, 20 % LH, 10 % VH). The results (fig.**??**) exhibit a characteristic plateau between the Knee



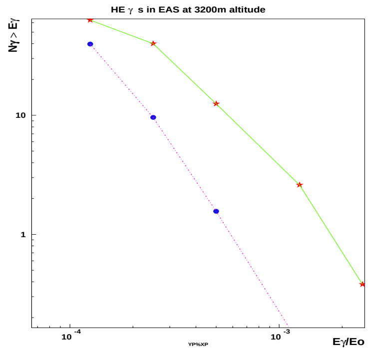


Fig. 3. a: $\mathrm{T}_{\mathrm{max}}$ versus energy with diquark breaking. **b** T_{max} with diquark mechanism (3 valence quark interacts independantly, reombined as pions, no more leader **b**:event at Tian-Shan

and about 100 PEV. Similarly (fig.3.b) the fragmentation region in EAS of 30 PeV at Tian-Shan altitude disappears (fig.3.b) in the case of the neutral channel of the diquark breaking. At Tian-Shan altitude, the neutral channel turns to an excess of the electron size, increasing the trigger of such showers.

4. Discussion

Even if those procedures can explain via diquark breaking the coplanar emission, the centauro's and anticentauro's, the behaviours of $\mathrm{T}_{\mathrm{max}}$, a sterile channel (turning to μ's and ν's) would be necessary to explain the Knee itself. New measurements on high energy muons in EAS are necessary for additive tests (for instance, for 220 GeV muons, a kink was seen in KGF experiment, but not confirmed with Moscow experiment in $\mathrm{N}_{\mu} > 220$ GeV versus N_e).

Further calculations are also necessary to measure the validity of the invariant mass method and the estimation of the origin of the γ-ray families.

Several ambiguities remain 40 years after the establishment of the Knee and it is worthwhile to investigate simultaneously age parameter, absorption length, muons to point out some coherent footprint of a change of interaction.

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